PRIED
Policy Research Institute
for Equitable Development

Swarm Grids: The next phase of the Solar Boom

Contents

Pakistan's Energy Paradox: A People-Led Transition

Pakistan's solarization was not driven by government policy — the people drove it. Households, farmers, businesses, and industries mobilized their finances to ensure a reliable and affordable supply of electricity for their needs. The factors of reliability and affordability vary from household to household. Still, the common thread is clear: solar has added tangible value by raising living standards for those who adopted it. Table 1 shows the regional distribution of installed solar capacity by connection type (GW), based on PRIED's 2025 survey.

Regions	Net Metering (GW)	Non-Net Metered (GW)	Off-grid (GW)
Punjab	4.9	8.49	4.39
KPK	0.64	5.47	2
Sindh	0.03	3.53	1.44
Balochistan	0.02	0.93	0.48
ICT	0.44	0.57	0.01
Total	6.03	19	8.31

Residential	Commercial	Industrial	Agriculture	Total
16.66	3.73	7.91	5.04	33.34

Source: PRIED's on-ground survey 2025

Pakistan has more solar capacity than it knows what to do with — and still can't keep the lights on or provide reliable supply of electricity across the country. Pakistan has imported 50 GW of solar panels against just 41 GW of installed generation capacity nationwide[1]. PRIED estimated 33 GW of installed solar capacity as of July 2025; new estimates by Renewables First and Herald show that it now stands at 38GW in 2026. Yet brownouts, blackouts, and long load-shedding hours remain everyday realities.

1. Solar Boom: A Challenge or an Asset

The system operator describes solar as the biggest threat to the grid, rather than an asset. The main thing driving this view:

- **Grid stress** — DISCOs report reverse power flow and duck curve issues as a growing operational challenge.

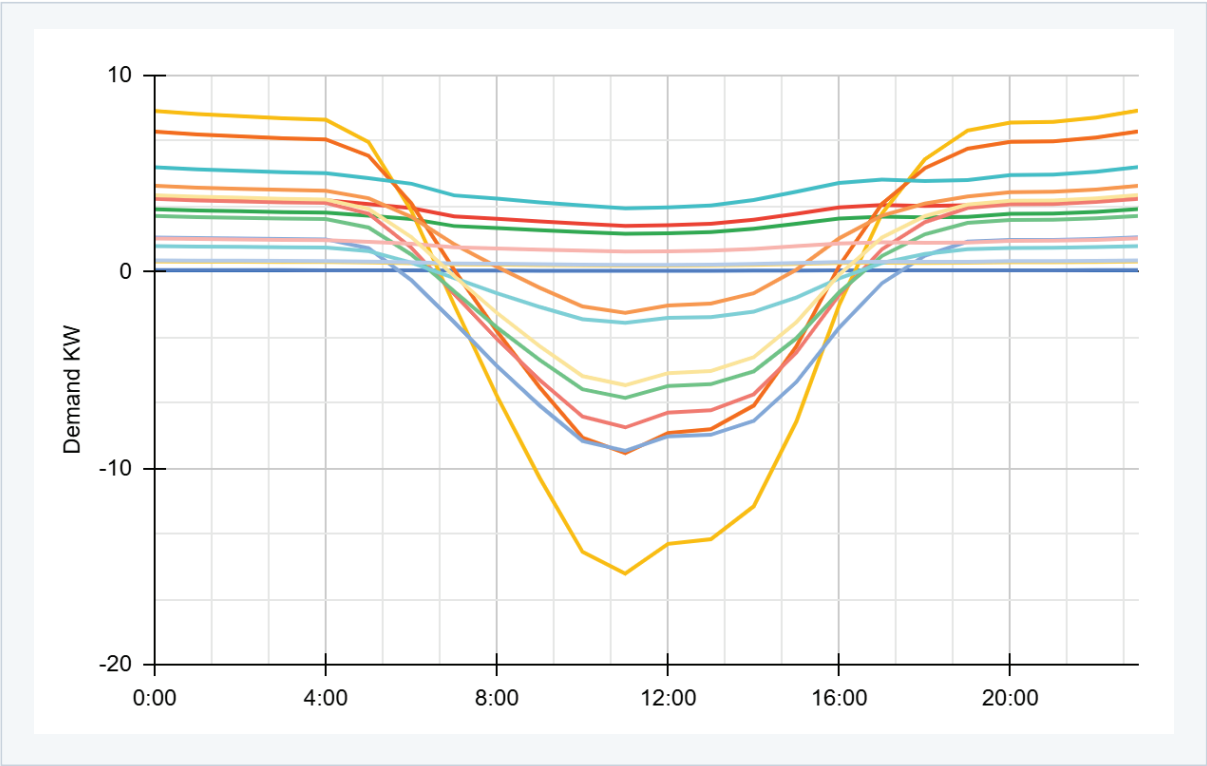

Figure 1: The duck curve observed from the load profiles of the Urban case cluster in Islamabad [1]

- **Inequity across sectors** — The second factor is cost shifting to non-solar consumers, as solar adopters reduce their contribution toward the costs needed to maintain the grid. Moreover, PRIED's study finds that the benefits of solar are distributed unevenly across residential, industrial, and commercial users. For the case of the residential sector, Figures 2 & 3 show that the wealthier households

1 Pakistan Electricity Review - Renewables First

2 Source:Harnessing Pakistan's Solar Revolution: A Techno-Economic Assessment of Swarm Electrification (PRIED)

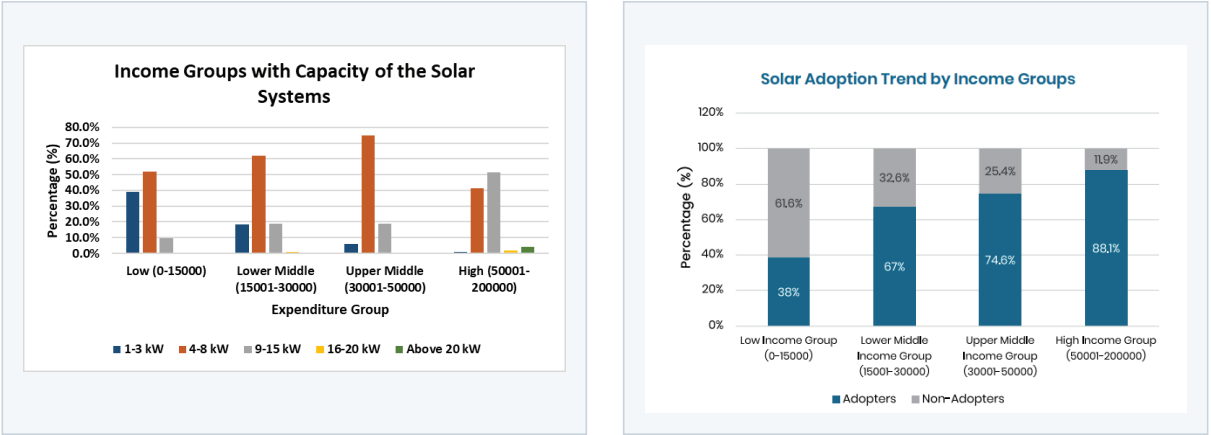

Figure 2&3: Solar Adoption across different income Levels in the residential sector (Source: Shouting from Rooftop (PRIED)).

The task ahead, then, is twofold: reframe solar as an asset and address the underlying inequities that are causing authorities to see it as a threat.

2. Coordinating Existing Assets

Rather than treating millions of individual solar installations as isolated liabilities, the proposed transition agenda is to coordinate existing distributed assets — pooling solarized households together so their combined capacity can be managed, shared, and monetized collectively.

This is the core idea behind a swarm grid. A swarm grid essentially is an organic, decentralized energy system that interconnects individual household power sources — solar panels and batteries — into a local sharing network. Essentially, the setup is somewhat similar to a microgrid, but instead of being built top-down, it grows organically as households with solar home systems (SHSs) begin sharing electricity.

A swarm grid is a digitally coordinated local electricity network in which households and businesses can:

- use their own solar power;
- store electricity in individual or shared batteries;
- sell surplus power to nearby consumers;
- buy electricity from neighbours;
- use the national grid as backup; and
- eventually provide flexibility services to the distribution company.

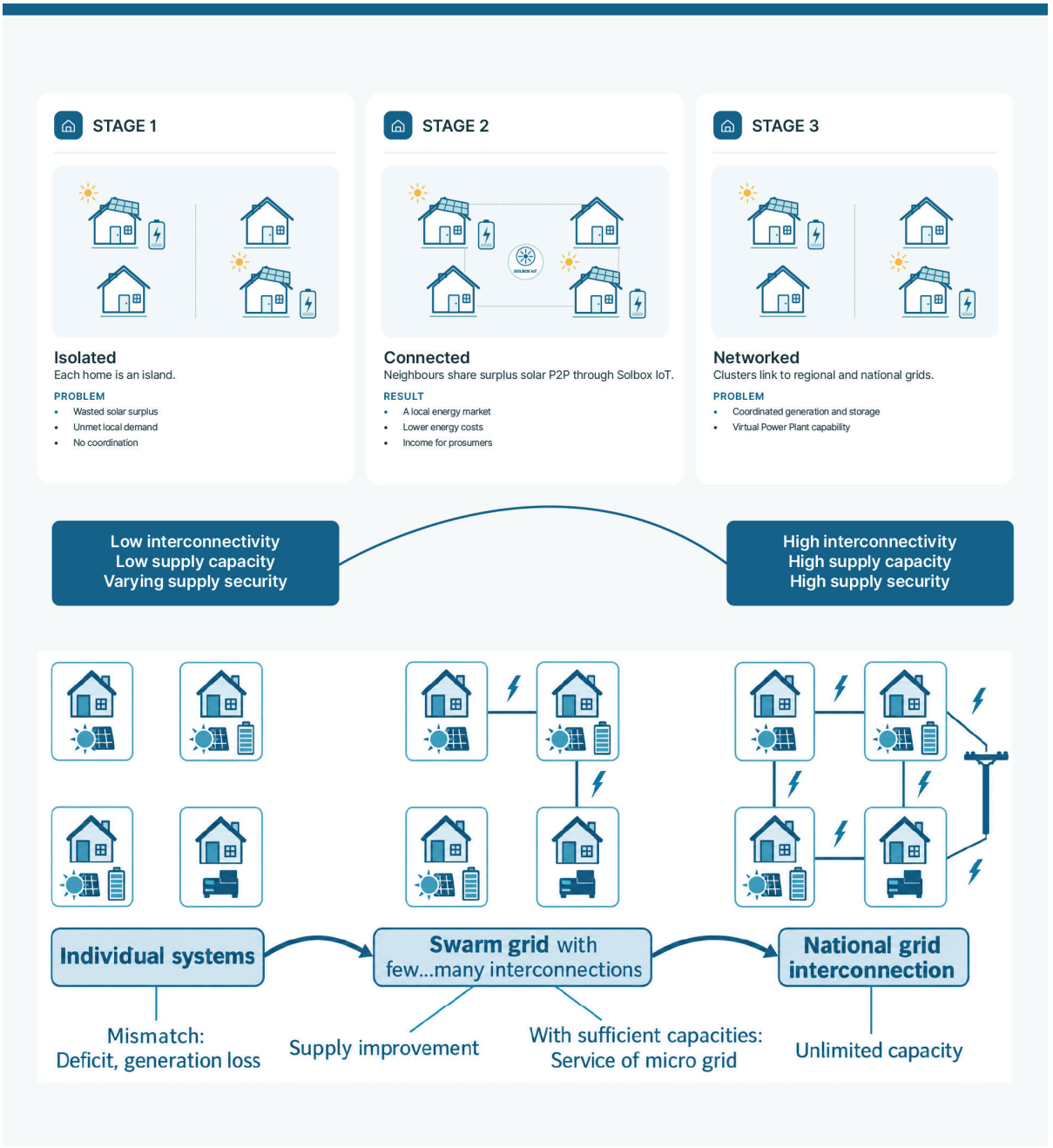

Figure 4: Evolution of a Swarm Grid

How Swarm Grids Share Value Locally/ How it works?

A swarm grid can make the energy transition more inclusive by enabling both solar and non-solar households to benefit from locally generated electricity. Prosumers can earn from surplus solar, while non-solar consumers gain access to affordable local power. At the same time, businesses can benefit from greater reliability, communities can create local jobs, and utilities can reduce peak stress to some extent. Surplus solar can be used progressively—from meeting household demand and charging batteries to supplying nearby consumers, EVs, pumps, and businesses—before any remaining electricity is exported to the grid.

3. Testing Feasibility: Two Case Studies

PRIED tested the feasibility of swarm-grid in urban and rural settings using household surveys, solar resource data, and an hourly dispatch model. The detailed analysis is available in the main report on swarm electrification.

Criterion	Urban Case	Rural Case
Setting	Dense urban neighbourhood with diverse residential and commercial loads	Scattered households with smaller solar systems
Technical feasibility	Feasible through coordinated local electricity sharing	Feasible
Economic viability	Potentially viable as a commercial swarm-grid business	Requires upfront investment support for the essential distribution network as well as community capacity-building sessions
Tariff model	Commission-based: Prosumers and consumers agree on an average rate of Rs. 20 per unit to buy/sell electricity. A 1–5% fee (set by prosumers) is paid to the swarm grid operator per transaction.	Commission-based: prosumers and consumers agree on an average rate of Rs. 20 per unit to buy/sell electricity. A 1–5% fee (set by prosumers) is paid to the swarm grid operator per transaction.
Key lesson	Urban swarm grids can support a viable local energy business.	Interconnecting small solar systems provides a steady income stream for prosumers while providing cross-sector opportunities—such as enabling IT infrastructure for schools through reliable, local power access.

Swarm grids are technically feasible in both contexts, but their economic model differs. Urban systems can potentially operate commercially, while rural systems may need targeted, time-bound support to overcome high upfront costs and low energy density. To elaborate, the urban side can be catered to by a private investor, i.e., a swarm grid operator or, in a subsequent phase with grid interconnection, a virtual power plant operator, but for the rural case, the investor will be attracted first by covering or subsidizing the initial upfront cost for the system. In both cases, P2P trading must be combined with storage, appropriate backup, and sufficient local demand.

4. The Core Obstacle: Regulation

The biggest hurdle identified for this setup is that P2P electricity trading is currently restricted — the regulatory framework in Pakistan restricts third-party sales on a distribution company's territory. Without legal clarity on who can sell, at what price, and under what settlement mechanism, no swarm grid can operate at scale. An entirely new P2P regulation is needed before this model can move from feasibility study to real deployment. The regulations need to define prosumer, consumer, and platform-operator roles in these regulations. It must establish transaction settlement standards (hourly metering, mobile money integration). The regulations must create a licensing pathway for swarm grid operators distinct from conventional DISCOs.

The table below presents the main transition agenda items with implementation timeline

Swarm Electrification Adoption roadmap for Pakistan

Timeframe	Next Steps	Lead Actor(s)
Short-term (0–1 year)	Create P2P trading regulations — clear rules covering participation, transactions, settlement, and the responsibilities of each actor in the system	NEPRA (regulatory authority)
	Standardize solar equipment on the distribution network, with enforcement and penalties for non-NEPRA-approved installations	NEPRA, in coordination with DISCOs (enforcement at connection/ metering point)
	Open the retail electricity market under CTBCM, enabling greater participation from prosumers and consumers	ISMO (market operations under CT-BCM), NEPRA (regulatory approval)
	Position swarm electrification as a resilience asset against supply shocks (e.g., Hormuz Crisis)	Ministry of Energy / Power Division (strategic framing), Provincial Energy Departments
	Attract investors by subsidizing upfront costs	Ministry of Planning to leverage funding under public sector development programme Provincial governments, development finance institutions (DFIs)
Medium-term (1–3 years)	Plan and implement pilots — rural remote areas first, then an urban grid-connected setting	DISCOs (grid interconnection), local government/community energy cooperatives (rural rollout), NEPRA (oversight)
	Mobilize climate finance and access carbon markets for rural swarm-grid deployment	Ministry of Climate Change
	Develop flexible business models — e.g., rewarding peak-hour feed-in with higher tariffs or targeted incentives	Swarm Grid Operator/ Company
	Develop Pakistan-adapted energy technology to design systems such as *SolBox*[3] that are suited to Pakistan's grid conditions and voltage levels.	Swarm Grid Operator/ Company
Long-term (3–5+ years)	Enable new business models for local energy — "prosumer-entrepreneurs" earning through generation, storage, sharing, and management of electricity	ISMO (open retail market structure)
	Shift electricity demand toward solar hours to encourage households and businesses to run flexible loads, such as water pumping, cooling, and EV charging, when solar power is most abundant	Swarm Grid Operator

3 A smart power-control device installed in a household that connects its solar home system to a small direct-current (DC) grid shared with neighbouring homes, automatically managing the buying and selling of electricity between them.

An agenda for a women-inclusive transition, to be mandated by the authorities on swarm-grid operating companies, which they must adhere to:

Agenda Item	Description
Asset registration	Default swarm-grid accounts, metering, and payment identities to be registerable in either spouse's name — not automatically the male head of household
Mandatory inclusion in installation and handovers	Require women in the household to be present for consultations and system handovers, alongside basic solar-use training for female users
Build women-inclusive operations	Train both men and women in participating households to operate, maintain, and manage swarm-grid systems
Women-led O&M teams	Pilot women-led operations and maintenance crews for swarm-grid clusters, rather than defaulting to male technicians
Targeted financing	Offer subsidies and low-interest loans specifically for female-headed households joining swarm-grid networks, alongside gender-disaggregated data collection to track whether uptake and benefits are actually reaching women